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BY Wes Sanderson
Wes Sanderson

SUPERVISED BY Christopher L. Irving
Christopher L. Irving

APPROVED BY F. M. Watson III
F. M. Watson, III

DISTRIBUTION:

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ABSTRACT

Image analysis data is presented herein to compare the usefulness of the Rotap, Kason, and P. M. sieve shakers as methods for separating tobacco particles by size. Discussions are also made of modifications to standard separators and alternate separation methods that were tested. Particle size distribution curves for the P.M. shaker, evaluated with the new round sieve screens (6, 12, 20, 35 mesh) proposed by Q.A., from Marlboro, Marlboro Ripper Shorts, Diet, RL-150B, DBC bright, DBC burley, and MT turkish are provided.

TABLE OF CONTENTS

SUMMARY OF RESULTS

Literature searches have indicated that sieve testing is currently the only method commercially available for classifying large quantities of tobacco by size. Numerous studies have been done on the test parameters that affect the accuracy of sieve weight fractions on the standard P.M. sieve shaker. However, none have gone so far as to report the actual particle size distribuiton of the individual fractions. Using image analysis techniques to measure individual particles, this study has evaluated three sieve shakers: the Rotap, Kason, and P.M., along with minor modifications to them and some alternative separating ideas.

The following observations were evident from the data gathered:

I. As the screen opening size decreases the average particle size decreases. However, particle size distributions overlap from screen to screen.

II. Particle size distributions can be generated and the distributon curves for a single tobacco type always fall in the correct order respective of screen opening size.

III. Sieving analysis results will be most valid when a direct comparison of like tobacco types is made.

IV. Average particle size for a given screen and screen combination is repeatable and a function of tobacco type and/or blend.

V. Particle size standard deviation, on any screen, is typically between 1/4 and 1/2 of the average size.

VI. Regardless of shaking motion, particles longer than the actual screen opening are being passed. The average particle size is always considerably larger than the opening size it passed through.

VII. Observations from high speed video films indicate that the inital orientation of particles to the screen and reorientation of particles, due to vertical vibrations, is the largest source of error in classifying particles by size from sieving. Efforts to lower the particle size variation, due to the reorientation, by reducing vertical vibrations were unsuccessful.

VIII. Tests with perforated plates replacing sieve screens did not show a lower particle size variation.

IX. Attempts at an alternate separation method of manipulating particles in a moving air stream showed separations with particle size variation no better than normal sieving.

X. It could not be proven in the scope of this study that any shaker, any shaker modification, or any alternative separation method, had less particle size variation (narrower distribution) than the P.M. sieve shaker with round screens (6, 12, 20, 35 screen and pan combination).

XI. Image analysis is required if a more accurate indication of particle size distribution is required. Generally the most accurate image analysis results are achieved by randomly sampling particles from a prefractionated sample. This requires a routine sieving and then a hand selection and mounting of particles. The time required to prepare the particles and generate size data for the individual particles is approximately one and one half hours per sieve sample (6, 12, 20 mesh screens) for one technician.

XII. Care should be taken when comparing sieve results from different tobacco types and/or sieve screen combinations.

INTRODUCTION

The development of an accurate and reproducible method for the measurement of tobacco particle size distribution is necessary to understand the sources and causes of particle size degradation during tobacco processing. Several cigarette physical properties, such as coal strength, rod firmness, and loose ends, have been related to the tobacco particle size distribution within the finished cigarette.

The ideal particle measurement system would be an automated device that actually measures individual particle dimensions, however; sieve testing is currently the only method commercially available, or in wide spread use, for classifying large quantities of particles by size in the tobacco or food industries.

Philip Morris currently classifies its tobacco products on an in-house designed sieve screen shaker. Sieve screens are designed to measure particle size and particle size distribution of materials where all three axes of the particles are somewhat equidimensional.[1] Tobacco particles differ considerably from these ideal conditions and therefore sieve analysis results give less than perfect indications of particle size.

The work discussed here provides data to determine the accuracy of tobacco particle size measurement by sieve analysis. Data is presented from three sieve shakers; the Rotap, Kason, and P.M.; along with a discussion of various modifications to these and alternate ideas for particle separation.

Image analysis was used as a standard for evaluation of separation methods. The Hamamatsu Image Analysis System, a video microcomputer controlled system with some statistical capabilities, was used throughout the entire study.

Particle area and diameter were measured with the Hamamatsu system. Diameter is defined in terms of the four extreme points of the particle being viewed. It is the longest cord that will connect any of the top most, bottom most, right most, and left most points as viewed in the X and Y coordinates by the systems's camera. The diameter most closely resembles the length of a particle. The Zeiss Videoplan, a microcomputer controlled system with statistical capabilities, was used in the early stages of the study to measure particle length. This system required manual tracing of particles on a digitizer tablet. In addition, the Zeiss unit was also capable of projecting a particle image from a microscope on to a video monitor where the image could be traced and measured with a cross-hair cursor. Both image analysis systems required a "mounting" of completely separated particles. This sample preparation is very tedious and time consuming.

DISCUSSION AND PRESENTATION OF DATA

I. Rotap Sieve Shaker

Initially it was believed that the linear back and forth motion of the P.M. sieve shaker tended to align the tobacco particles in the direction of motion. Once aligned, the particles would then tend to insert themselves into the screen opening, somewhat like threading a needle, causing particles longer than the screen opening to be passed by the screen. A rotational shaking motion was suggested to break up the alignment believed to be happening. The Rotap, model B, sieve shaker provided this rotational shaking motion and in addition, it had an attachment to enhance the sieving by vertically tapping the screen stack.

A. Sieving conditions - Rotap

Tests were first conducted to determine the optimum operating conditions for sieving cut filler tobacco. Table 1 shows the effects of varying loading weight (constant shaking time), and shaking time (constant loading weight). The loading weight was varied between 10 and 100 grams, in intervals of 10 grams, and then two runs were done at 150 grams, all while holding the shaking time constant at five minutes. The percent weight on the top, 4 mesh, screen significantly increased for the 150 gram loading. This indicated a possible weight overload and that the 100 gram loading would be a good and convenient loading weight. After establishing a standard loading weight, the shaking time was varied between 2.5 and 15 minutes. As expected, the percent weight on the top 4 mesh screen decreased as shaking time increased. The smallest amount of change appeared between 5 and 7.5 minutes, resulting in the 5 minutes shaking time being chosen.

TABLE 1

ROTAP OPERATING CONDITIONS

Loading Weight Tests
(Shaking Time Constant, 5 Minutes)

Tobacco Type - Marlboro Cut Filler
Screen Combination - 4, 6, 8, Pan

Loading Weight (Grams)	Weight On 4 Mesh (%)	Sample O.V. (%)
10	1.90	-
20	2.15	-
30	2.53	11.75
40	2.20	11.79
50	1.98	11.93
60	3.02	11.92
70	2.37	11.85
80	3.25	11.84
90	3.18	11.54
100	2.12	11.55
150	7.46	11.75
150 (2nd Replication)	5.93	11.76

Shaking Time Test
(Loading Weight Constant, 100 Grams)

Tobacco Type - Marlboro Cut Filler
Screen Combination - 4, 14, 35, Pan

Shaking Time (Minutes)	Weight On 4 Mesh (%)	Sample O.V. (%)
2-1/2	10.89	13.13
5	4.62	13.51
7-1/2	4.30	13.49
10	3.03	13.31
12-1/2	3.43	13.34
15	1.68	13.37

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B. Particle Size Distribution - Rotap

Using the aforementioned sieving conditions, the Rotap was evaluated next for particle size distribution. A sample of Marlboro cut filler was equilibrated at 75°F. and 60% R. H. and then five sieving replications were done using a 6, 8, 10, 14, 20 screen and pan combination. (Note that at this point no mention has been made of the optimum screen combination. It will be evident from further discussions that having the best screen combination is not necessary for this part of the evaluation.) Every screen fraction from each sieving run was saved and 150 particles from each fraction were measured on the Hamamatsu and the Ziess. Image analysis data showed that as the screen opening size decreased the average particle size decreased. However, in each case the average particle size trapped on a screen was larger than the screen opening it passed through. The tabulated results are shown in Table 2.

TABLE 2

ROTAP SIEVE SHAKER - IMAGE ANALYSIS DATA

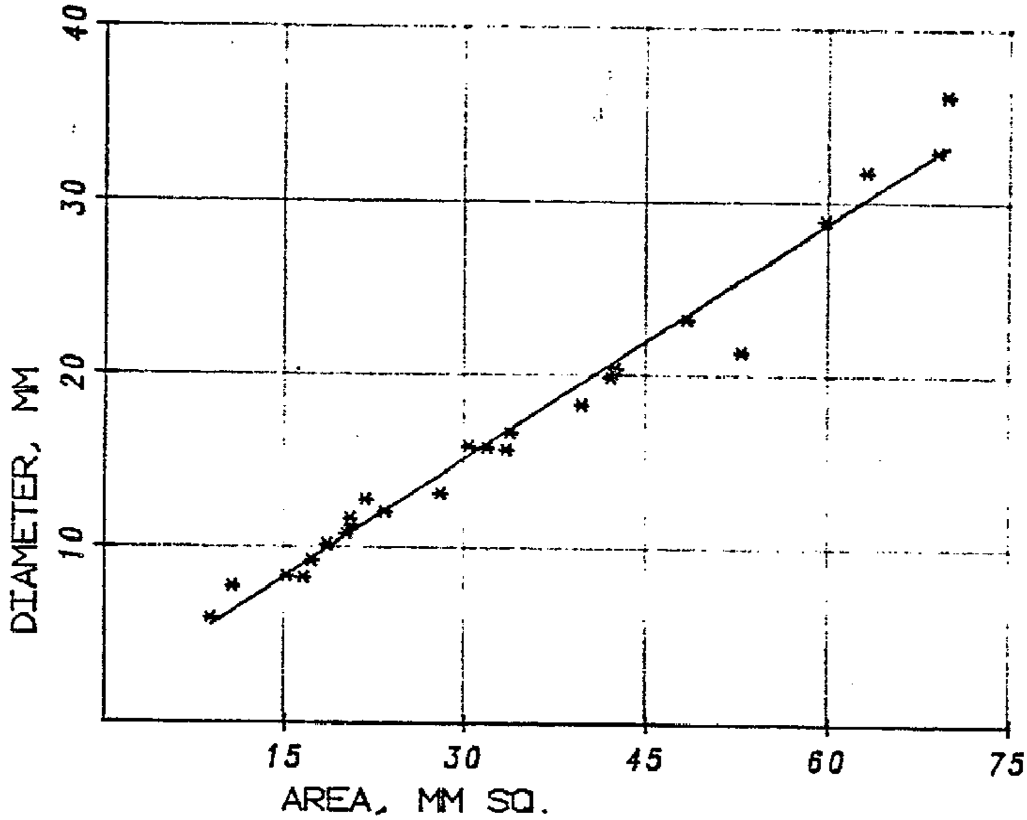
Marlboro Cut Filler

Mesh	Mesh Opening mm	Run 1	Run 2	Run 3	Run 4	Run 5	Total Average
		Average Diameter, mm					
6	3.33	21.4	36.2	31.8	33.0	29.0	30.3
8	2.36	16.7	23.3	18.3	19.9	20.4	19.7
10	1.65	12.8	15.8	13.2	15.7	15.9	14.7
14	1.17	10.2	12.1	11.7	11.3	10.8	11.2
20	0.83	6.0	9.3	7.8	8.3	8.4	8.0
		Average Area, mm^2					
6	3.33	52.9	69.8	63.1	69.0	59.8	62.9
8	2.36	33.8	48.4	39.7	42.1	42.5	41.3
10	1.65	21.8	31.9	28.0	33.5	30.4	29.1
14	1.17	18.6	23.4	20.5	20.6	20.2	20.7
20	0.83	8.9	17.3	10.7	16.6	15.2	13.7
		Average Length, mm					
6	3.33	30.6	44.2	36.8	39.3	34.6	37.1
8	2.36	22.6	29.3	23.4	24.4	24.7	24.9
10	1.65	15.0	19.2	15.2	18.7	17.5	17.1
14	1.17	11.2	13.4	12.9	12.5	11.6	12.3
20	0.83	6.8	10.0	8.9	7.7	8.4	8.4
Sample O.V.		10.12	12.73	12.91	12.02	12.24	12.00

The different types of measurements correlate well with each other indicating no bias from any one type of measurement. Chart 1 shows the average diameter plotted against the average area and Chart 2 shows the average area vs. the average length for the five runs. Plots of average sizes vs. size standard deviatons show a proportionality between the two. Chart 3 shows the relationship between the diameter averages and their standard deviations. Because this relationship exists it is reasonable to use this ratio, standard deviaton/ average, as a means to compare particle size variability. Table 3 shows a listing of the standard deviation/average ratio for particle diameter on each of the five sieving runs and five screen meshes. A two-way analysis of variance on the listed ratios indicates a significant difference in average diameter as a function of mesh size, while no evidence of a significant difference in average diameter is apparent from run to run. It is important to note at this point that the size standard deviation is betwen 1/4 and 1/2 of the average size, indicating a large size range distribution.

CHART 1

AVERAGE DIA. VS AVERAGE AREA
ROTAP SIEVE SHAKER – STANDARD SIEVING CONDITIONS
6,8,10,14,20 SCREEN AND PAN COMBINATION
MARLBORO CUT FILLER

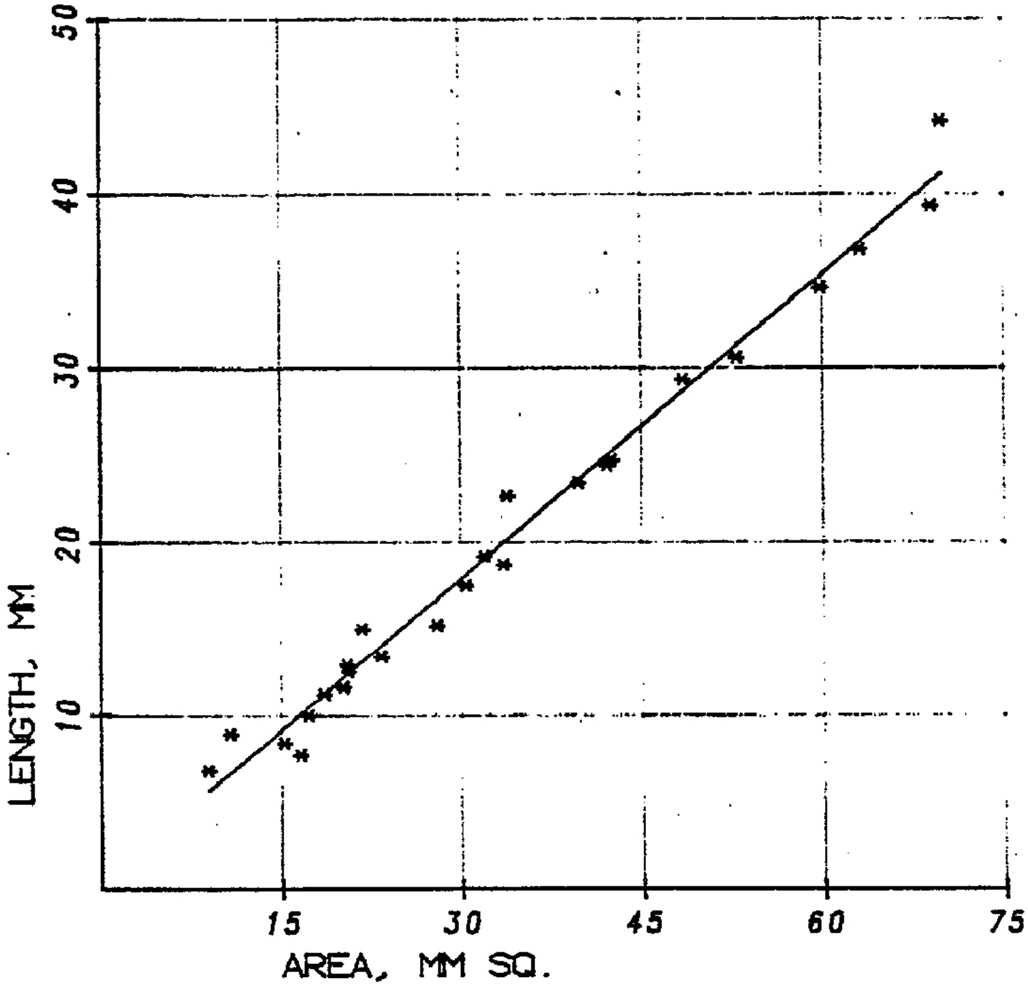


	R	SD	INT	SLOPE
*=	0.9883	1.308	1.508	0.455

WG1.CHT

CHART 2

AVERAGE LENGTH VS AVERAGE AREA
ROTAP SIEVE SHAKER – STANDARD SIEVING CONDITIONS
6,8,10,14,20 SCREEN AND PAN COMBINATION
MARLBORO CUT FILLER



	R	SD	INT	SLOPE
*=	0.9924	1.347	0.3882	0.5833

WG2.CHT

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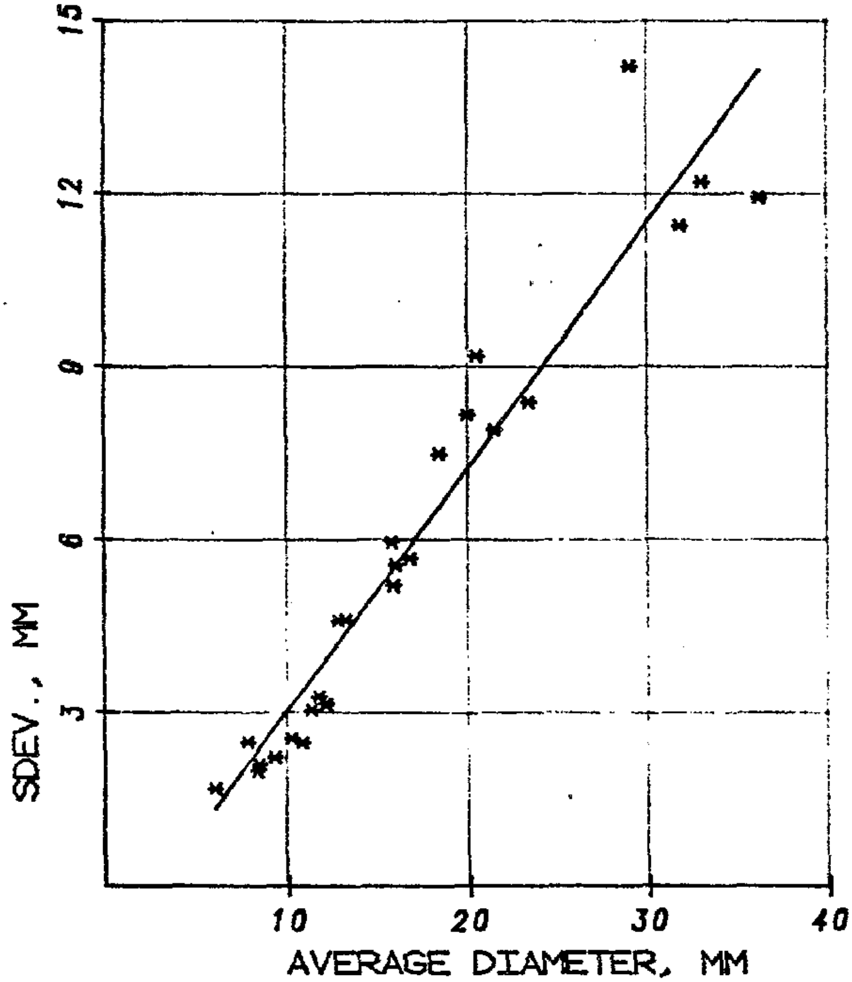
CHART 3

STANDARD DEVIATION VS AVERAGE DIAMETER
ROTAP SIEVE SHAKER – STANDARD SIEVING CONDITIONS
6,8,10,14,20 SCREEN AND PAN COMBINATION
MARLBORO CUT FILLER



	R	SD	INT	SLOPE
*=	0.9627	1.021	-1.201	0.4237

WG3.CHT

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TABLE 3

ROTAP SIEVE SHAKER

Standard Deviation/Diameter Average

	Run					
Mesh	1	2	3	4	5	Average
6	0.37	0.33	0.36	0.37	0.49	0.38
8	0.34	0.36	0.41	0.41	0.45	0.39
10	0.36	0.33	0.35	0.38	0.35	0.35
14	0.25	0.26	0.28	0.27	0.23	0.26
20	0.28	0.24	0.32	0.24	0.25	0.27

Tobacco Type - Marlboro Cut Filler

An inspection of the individual size values within a fraction shows that the distributions are log-normal. Keeping this in mind, Mr. John Tindall calculated a 95% statistical size range for each screen and type of measurement, by calculating the log mean and sigma and taking into account the size variation for a single tobacco particle including size variation due to sieving. The exponential of these numbers was then calculated for easier comparison. It is evident from these calculated size ranges, shown in Table 4, that the distributions for the different screens overlap quite a bit.

TABLE 4

ROTAP SIEVE SHAKER

Mesh	Average	Statistical 95% Range
	Diameter, mm	
6	30.3	12.6 - 61.7
8	19.7	8.4 - 39.4
10	14.7	6.9 - 27.6
14	11.2	6.5 - 18.1
20	8.0	4.2 - 13.8
	Area, mm^2	
6	62.9	30.9 - 122.5
8	41.3	20.3 - 81.0
10	29.1	14.7 - 57.8
14	20.7	10.1 - 39.2
20	13.7	7.0 - 28.2
	Length, mm	
6	37.1	18.1 - 72.4
8	24.9	11.9 - 47.7
10	17.1	8.3 - 32.9
14	12.3	6.0 - 23.3
20	8.4	4.1 - 16.5

Tobacco Type - Marlboro Cut Filler

The standard deviation/average ratio is a major contributor to the size range calculations as shown in the Appendix. An inspection of these calculations will show that the standard deviation/average ratio would have to decrease significantly to make the size ranges distinct. Since the standard deviation/average ratio has such a major effect on size range it is a good indicator with which to compare different types of separation methods.

C. High Speed Video Films - Rotap

In an effort to determine the cause of large particle size variation in sieve fractions, high speed video films were taken of a screen's cross section. A window was cut between two mating screens allowing observation of what fell to and through the screen. The video equipment had features for immediate playback, slow motion replay, stop frame action and reverse viewing. Three general observations were made from the films. First, particles longer than the screen opening were passing through the screen. Second, as the particles fell to the screen, some initially oriented themselves partially through the screen opening. As the shaking continued they would work their way through the opening. The third observation was that some particles reoriented themselves. Vertical vibrations would cause these particles to jump off the screen and fall back partially through the screen opening. It was felt that little could be done about the initial orientation, but possibly the reorientation could be prevented. Section II.C. discusses one method evaluated for preventing reorientation-air aided sieving on the P.M. sieve shaker. This was the most convenient shaker to test the idea that reorientation of particles due to vertical vibrations could be stopped by directing an air stream on the screen stack.

II. P.M. Sieve Shaker

A. Operating Conditions - P.M. Shaker Rectangular Screens

Loading weights and shaking times for the P.M. shaker were evaluated in the same manner as for the Rotap. Standard Q.A. operating conditions of 150 gram loading weights, cut filler, and 5 minute shaking times are verified by the data in Table 5.

Table 5

P.M. OPERATING CONDITIONS

Loading Weight Test
(Shaking Time Constant, 5 minutes)

Tobacco Type - Marlboro Cut Filler
Screen Combination - 10, 20, 30, 50, Pan

Loading Weight (Grams)	Weight On 10 Mesh (%)	Sample O.V. (%)
10	20.50	11.42
20	29.55	11.92
30	26.90	11.94
40	24.60	12.03
50	23.68	12.45
60	25.75	12.31
70	23.24	12.26
80	22.40	12.44
90	25.12	12.38
100	25.44	12.33
100 (2nd Replication)	23.16	12.21
150	26.95	12.66
150 (2nd Replication)	24.58	12.45
200	26.84	12.63
200 (2nd Replication)	25.19	12.82

Shaking Time Test
(Loading Weight Constant, 150 grams)

Tobacco Type - Marlboro Cut Filler
Screen Combination - 10, 20, 30, 50, Pan

Shaking Time (Mintues)	Weight On 10 Mesh (%)	Sample O.V. (%)
2-1/2	30.95	12.56
5	26.95	12.66
5	24.58	12.45
7-1/2	23.75	12.91
10	18.86	12.38

B. Particle Size Distribution - P.M. Sieve Shaker Rectangular Screens

A sample of Marlboro cut filler equilibrated at 75°F and 60% R.H. was sieved five times on the P.M. shaker with a 10, 20, 30, 50 screen and pan combination. Image analysis was done on 150 particles from the 10, 20, and 30 mesh fractions from each run. (Image analysis procedures make measuring particles < 30 mesh impractical). As expected, the average particle size decreased as the screen opening size decreased, but in each case the average particle size trapped on a screen was larger than the screen opening it passed through. Average particle size for the three screens and five runs are shown in Table 6.

Table 6

P.M. SIEVE SHAKER - RECTANGULAR SCREENS

Mesh	Mesh Opening MM	Run 1	Run 2	Run 3	Run 4	Run 5	Total Average
Diameter, mm							
10	2.00	18.2	18.3	17.3	19.2	17.6	18.1
20	0.85	13.3	10.5	11.4	11.1	11.8	11.6
30	0.60	8.5	7.2	7.7	7.4	7.1	7.6
Area, mm^2							
10	2.00	40.6	41.2	43.1	44.9	40.6	42.1
20	0.85	27.9	19.7	23.0	23.5	22.7	23.4
30	0.60	17.3	13.3	14.5	14.3	12.9	14.5
Length, mm							
10	2.00	20.7	19.6	20.4	21.3	20.0	20.4
20	0.85	14.6	11.7	12.2	11.8	13.4	12.7
30	0.60	8.9	7.5	7.0	7.1	7.4	7.6
Sample O.V.		13.13	13.33	13.29	12.79	12.86	13.08

Tobacco Type - Malboro Cut Filler

The size standard deviations are approximately 1/4 to 1/2 of the average sizes as was observed on the Rotap. A two-way analysis of variance on the standard deviation/average diameter ratios, listed in Table 7, can be used to show significant differences in average size as a function of screen opening, while no difference in average size between runs can be shown.

Table 7

P.M. SIEVE SHAKER - RECTANGULAR SCREENS

Standard Deviation/Diameter Average

Mesh	Run 1	2	3	4	5	Average
10	0.51	0.46	0.44	0.53	0.55	0.50
20	0.35	0.33	0.44	0.30	0.35	0.35
30	0.29	0.23	0.28	0.28	0.21	0.26

Tobacco Type - Marlboro Cut Filler

Calculated 95% statistical size ranges show a large overlap in the size ranges for the different screen sizes. This data is shown in Table 8.

Table 8

P.M. SIEVE SHAKER - RECTANGULAR SCREENS

Mesh	Average	Statistical 95% Range
	Diameter, mm	
10	18.2	6.5 - 40.9
20	11.6	5.6 - 21.6
30	7.6	4.4 - 12.2
	Area, mm^2	
10	42.1	19.8 - 95.2
20	23.4	9.8 - 47.5
30	14.4	6.8 - 27.1
	Length, mm	
10	20.4	8.0 - 43.4
20	12.7	6.6 - 22.4
30	7.6	4.0 - 13.1

Tobacco Type - Marlboro Cut Filler

C. Air Aided Sieving - P.M. Sieve Shaker

Tests were conducted on the P.M. sieve shaker to try to decrease particle size variation due to reorientation of particles as described in Section I.C., high speed video films. A hood was placed over the screen stack so that an air stream could be directed on the particles to negate vertical vibrations and stop reorientation. Marlboro cut filler was sieved under four test conditions and compared to four control sievings. Table 9 describes the test conditions.

Table 9

Air Aided Sieving Test - P.M. Sieve Shaker - Rectangular Screens

Test	Sample Placement	Air Flow Rate[3]
1	Paper Catcher[1]	700 ft/min
2	10 Mesh Screen[2]	700
3	Paper Catcher	450
4	10 Mesh Screen	450

[1]Normal location.

[2]Samples were placed on the 10 mesh screen and a fine mesh screen was attached to the paper catcher to help diffuse the air.

[3]Approximate flow rate, it was difficult to get a good reading at the point of application.

Table 10 shows that the percent weight left on the 10 mesh screen of the air aided test sample varied only slightly from the control samples.

Table 10

Air Aided Sieving

Sample	% Wt - 10 Mesh Screen
Control 1	29.89
Control 2	29.06
Control 3	29.61
Control 4	29.62
Test 1	30.90
Test 2	28.00
Test 3	31.25
Test 4	29.08

Tobacco Type - Marlboro Cut Filler

P.M. Shaker - Rectangular Screens

Image analysis was done on the fractions from Control 1, Test 2 and Test 3 to compare particle size variability. Examination of the standard deviation/average area ratios in Table 11 indicates that the air stream did not help to reduce particle size variation.

Table 11

PARTICLE SIZE - AIR AIDED SIEVING

	Control 1			Test 2		
Mesh	Avg. Area mm^2	S. Dev.	S. Dev./Avg.	Avg. Area mm^2	S. Dev.	S. Dev./Avg.
10	35.22	19.15	0.54	33.76	21.52	0.64
20	18.16	7.84	0.43	13.61	6.01	0.42
30	7.10	2.71	0.38	6.81	2.62	0.41

Test 3

Mesh	Avg. Area mm^2	S. Dev.	S. Dev./Avg.
10	28.57	17.86	0.63
20	16.94	7.12	0.42
30	6.46	2.62	0.41

Tobacco Type - Marlboro Cut Filler

P.M. Sieve Shaker - Rectangular Screens

D. P.M. Sieve Shaker-Round Screens

Over the past year considerable work has been done by Q.A. and Engineering in evaluating changes to the P.M. shaker to increase the reliabilty of results. Their major objectives were to evaluate the equipment and testing procedures being used and to investigate any changes that might increase the reliability of results. The following conclusions were presented in Ms. K. A. Stover's study:[2]

> The rectangular screens should be replaced with round sieve screens, using ASTM grade wire, that are manufactured by a sieve screen manufacturer, Tyler Industrial Products Inc. Continue using the five minute shaking time, the 150 gram sample size (cut filler), and the 3/4 inch shaking stroke. Mesh combinations other than the 10, 20, 30 and 50 sizes can give better, more reliable results.

Ms. Stover and Mr. Bob Jensen have further recommended a switch to a 6, 12, 20, 35 screen and pan combination along with an elaborate initial and ongoing calibration procedure. Their reasoning behind the screen combination choice was that it separates the sample fairly evenly and it was more repeatable than other combinations that were tested. Preparations to change the P.M. sieve test by the above recommendations are under way.

E. Particle Size Distribution - P.M. Shaker Round Screens

The scope of this study went a little further to determine the particle size distributions on the 6, 12, 20, 35 screen and pan combination. At the same time we wanted to test a theory that screens that were unbounded (no screen above it) had more particle size variation than screens that were bounded. Five different tobacco types were tested on

the Q.A. shaker in the M/C Diet lab with 6, 12, 20, 35 and 4, 6, 12, 20, 35 screen and pan combinations. Five sieves, from three batches, were run on Marlboro filler, Marlboro ripper shorts (over 14 mesh), and Diet sampled from the M/C. Three sieves were run from one batch of shreded RL-150B and uncased cut DBC bright made at R&D on the small scale system. An inspection of the standard deviation/average ratios, shown in Table 12, for the percent weight on the bounded and unbounded 6 mesh screen shows that for the five tobacco types tested the unbounded 6 mesh screen is less variable for all the types except the RL. Also, for the ripper shorts, bright and RL, (4, 6, 12, 20, 35 combination), the combined percent weight on the 4 and 6 mesh screens is less than 1% of the total weight seived.

Table 12

AVERAGE SIEVE FRACTIONS
P.M. SIEVE SHAKER - ROUND SIEVE SCREENS

Marlboro

Mesh	Avg. % Weight	S. Dev.	S. Dev. Avg.	Avg. % Weight	S. Dev.	S. Dev. Avg.
4	-----	----	----	5.05	1.06	0.21
6	21.62	2.11	0.10	10.47	1.45	0.14
12	31.80	1.18	0.04	34.91	1.96	0.06
20	36.04	1.23	0.03	37.61	1.47	0.04
35	7.53	0.64	0.08	8.76	0.70	0.08
P	3.21	0.43	0.13	3.21	0.22	0.07
(OV)	13.33			13.50		

Diet

Mesh	Avg. % Weight	S. Dev.	S. Dev. Avg.	Avg. % Weight	S. Dev.	S. Dev. Avg.
4	-----	----	----	1.78	0.39	0.22
6	11.90	0.77	0.06	7.19	0.70	0.10
12	34.11	1.12	0.03	35.53	1.82	0.05
20	44.20	0.93	0.02	45.03	1.66	0.04
35	7.87	0.76	0.10	8.50	0.82	0.10
P	1.92	0.31	0.16	1.91	0.25	0.13
(OV)	10.71			10.23		

Marlboro Ripper Shorts

Mesh	Avg. % Weight	S. Dev.	S. Dev. Avg.	Avg. % Weight	S. Dev.	S. Dev. Avg.
4	-----	----	----	0.24	0.15	0.63
6	1.43	0.18	0.13	0.94	0.43	0.46
12	22.99	2.35	0.10	22.85	4.21	0.18
20	54.73	1.46	0.03	59.69	4.05	0.07
35	17.22	2.69	0.16	14.50	5.67	0.39
P	3.60	1.06	0.29	1.76	1.94	1.10
(OV)	15.48			15.20		

Bright

Mesh	Avg. % Weight	S. Dev.	S. Dev. Avg.	Avg. % Weight	S. Dev.	S. Dev. Avg.
4	-----	----	----	0.96	0.07	0.07
6	7.94	0.30	0.04	4.86	0.73	0.15
12	26.69	0.37	0.01	31.47	0.52	0.02
20	54.08	0.41	0.01	51.56	1.90	0.04
35	9.66	0.22	0.02	9.36	0.70	0.07
P	1.63	0.17	0.10	1.79	0.13	0.07
(OV)	12.17			12.32		

RL

Mesh	Avg. % Weight	S. Dev.	S. Dev. Avg.	Avg. % Weight	S. Dev.	S. Dev. Avg.
4	-----	----	----	0.10	0.03	0.30
6	0.74	0.12	0.16	0.32	0.02	0.06
12	13.05	0.40	0.03	17.25	0.29	0.02
20	61.82	0.82	0.01	57.68	1.25	0.02
35	17.11	0.59	0.03	16.57	1.08	0.07
P	7.27	0.72	0.10	8.08	0.21	0.03
(OV)	14.23			14.21		

PM3000984385

Comparing the standard deviation/average area ratios, shown in Table 13, indicates that the unbounded 6 mesh screen has less particle size variation for Marlboro and Marlboro Ripper shorts. The bounded and unbounded 6 mesh screens have approximately the same particle size variation for bright while the bounded 6 mesh was less variable for the Diet and RL. The aforementioned results indicate that adding the 4 mesh screen to the 6, 12, 20, 35 screen and pan combination did not significantly improve the particle size variation.

Table 13

PARTICLE SIZE
P.M. SIEVE SHAKER - ROUND SCREENS

Marlboro

Mesh	Avg. Area, mm^2	S. Dev.	S. Dev. / Avg.	Avg. % Area, mm^2	S. Dev.	S. Dev. / Avg.
4	----	----	----	77.5	36.4	0.47
6	63.4	28.6	0.45	61.6	29.6	0.48
12	32.7	16.3	0.50	34.2	17.7	0.52
20	19.4	7.8	0.40	18.4	8.2	0.44

Diet

Mesh	Avg. Area, mm^2	S. Dev.	S. Dev. / Avg.	Avg. % Area, mm^2	S. Dev.	S. Dev. / Avg.
4	----	----	----	58.9	30.2	0.51
6	40.7	17.4	0.43	40.5	15.1	0.37
12	25.8	10.1	0.39	24.6	9.6	0.39
20	16.4	5.8	0.35	15.5	5.2	0.34

Marlboro Ripper Shorts

Mesh	Avg. Area, mm^2	S. Dev.	S. Dev. / Avg.	Avg. % Area, mm^2	S. Dev.	S. Dev. / Avg.
4	----	----	----	40.8	19.8	0.49
6	41.7	16.9	0.41	43.8	20.8	0.47
12	28.5	11.6	0.40	26.4	11.0	0.42
20	19.9	7.6	0.38	14.8	6.6	0.44

Bright - Uncased

Mesh	Avg. Area, mm^2	S. Dev.	S. Dev. / Avg.	Avg. % Area, mm^2	S. Dev.	S. Dev. / Avg.
4	----	----	----	61.4	49.2	0.80
6	68.2	39.3	0.58	77.0	44.6	0.58
12	51.3	26.6	0.52	48.9	32.0	0.65
20	22.9	11.2	0.49	21.1	10.8	0.51

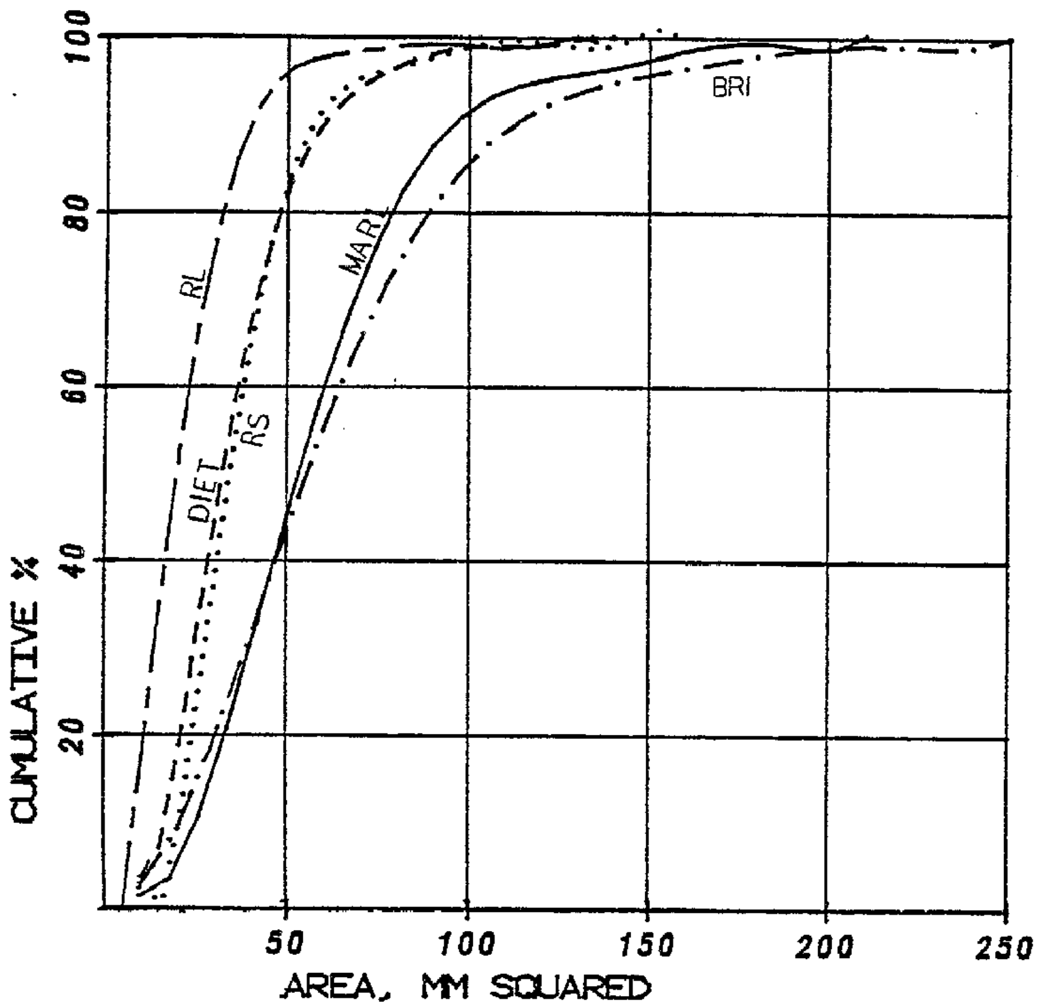
RL-150-B

Mesh	Avg. Area, mm^2	S. Dev.	S. Dev. / Avg.	Avg. % Area, mm^2	S. Dev.	S. Dev. / Avg.
4	----	----	----	24.1	24.2	1.00
6	26.1	18.2	0.70	19.7	12.0	0.61
12	24.7	10.8	0.44	25.0	10.6	0.43
20	16.5	6.9	0.42	14.1	5.1	0.36

Chart 4 shows the 6 mesh screen area distribtuions for the five tobacco types tested on the 6,12,20,35 screen and pan combination. The largest differences in tobacco types are represented by this curve. The curves are distinctive and a function of the tobacco type and/or blend. Chart 5 shows the area distributions for the 6,12 and 20 mesh screens for Marlboro cut filler. As with all the tobacco types tested these curves always fall in the correct order respective of screen size for a particular tobacco type.

CHART 4

PARTICLE SIZE DISTRIBUTION — 6 MESH SCREEN
MARLBORO,MARLBORO RIPPER SHORTS,DIET,RL,BRIGHT
6,12,20,35 SCREEN AND PAN COMBINATION

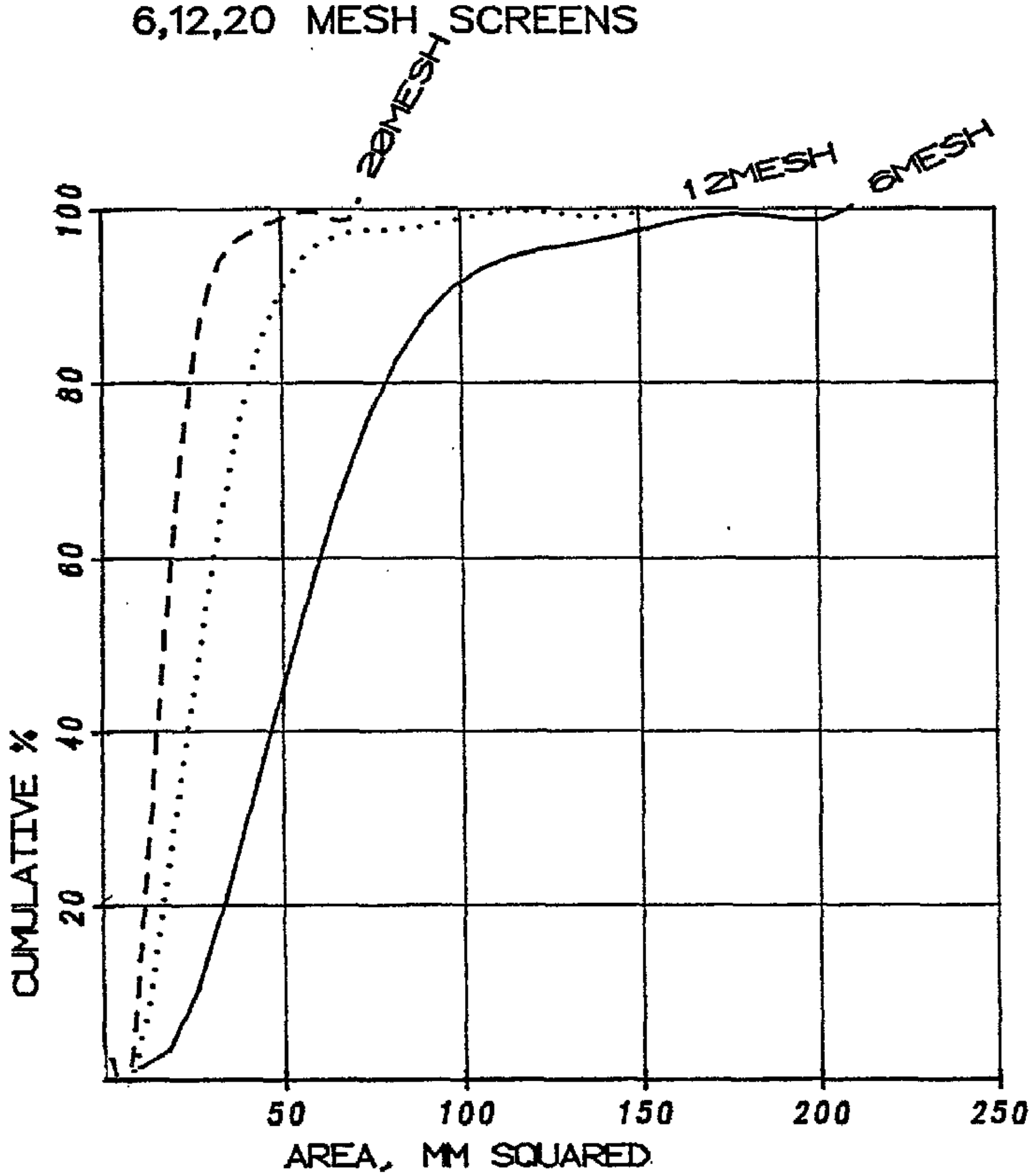


PM SIEVE SHAKER — ROUND SCREENS

PM3000984389

CHART 5

MARLBORO PARTICLE SIZE DISTRIBUTION
CUMULATIVE % VS AREA
6,12,20 MESH SCREENS



PM SIEVE SHAKER - ROUND SCREENS
6,12,20,35 SCREEN AND PAN COMBINATION

7/30/82

REPA.CH1

PM3000984390

Testing of tobacco types was continued to generate size distribution curves for MT turkish and DBC burley. MT turkish and DBC burley, processed and cut small scale at R&D, was sieved and submitted for image analysis along with a sample of DBC burley, processed and cut large scale at R&D. The area distribution curves for the MT turkish, shown in Chart 6, fall in the correct order for the 6,12, and 20 mesh screens respective of screen size as observed with the initial five tobacco types that were tested. Area distribution curves for the DBC burley cut large and small scale also fell in the correct order, but there was a size advantage evident in the burley cut small scale. This is shown in Chart 7. This seemed a bit confusing at first, especially after an inspection of the sieve fractions for the burley shown in Table 14. No significant differences in sieve fractions could be seen between the DBC burley cut large and small scale.

Table 14

DBC BURLEY

LARGE AND SMALL SCALE

R&D PRIMARY O/C

SIEVE FRACTIONS

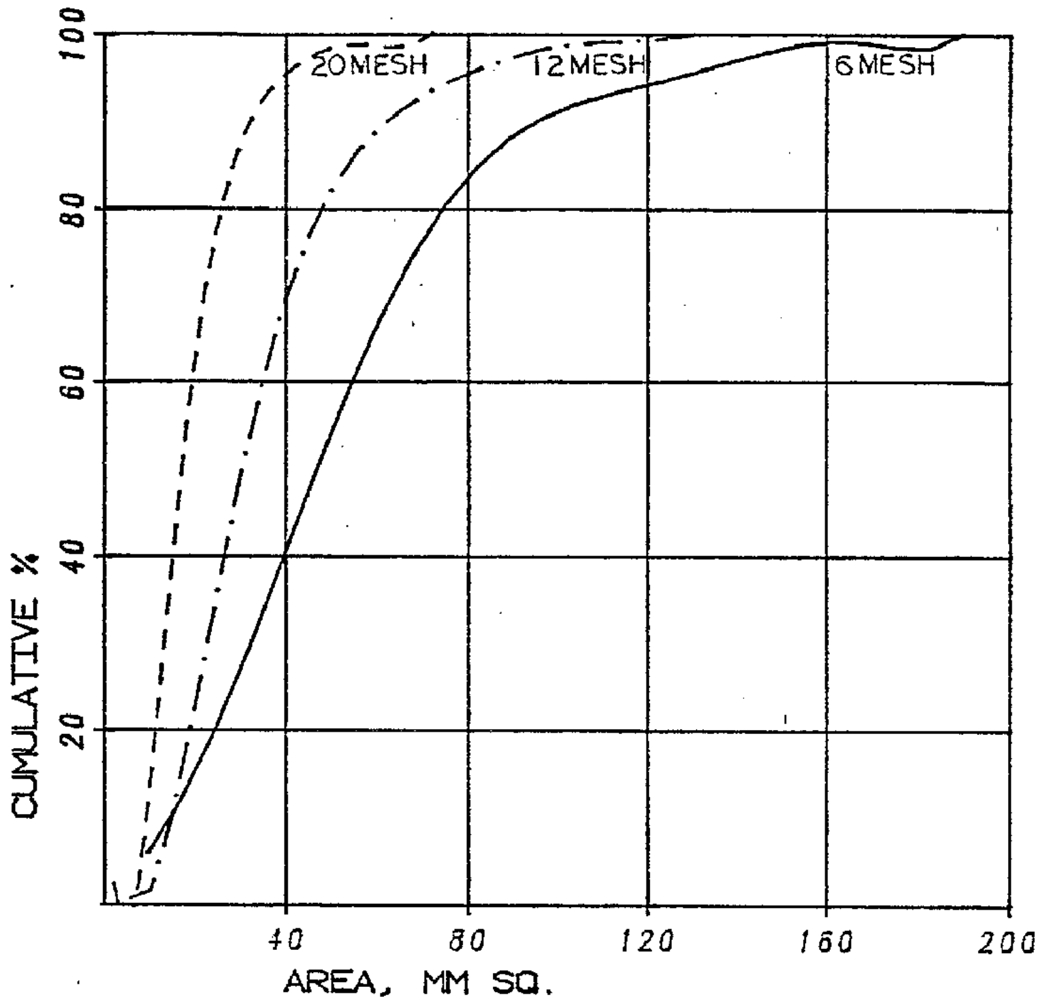
P.M. SIEVE SHAKER - ROUND SCREENS

(Avg. of 5 Replications)

Mesh	Small Scale % Wt.	Large Scale % Wt.
On 6	12.0	11.0
On 12	29.6	29.6
On 20	46.9	42.9
On 35	9.5	14.0
On Pan	1.9	2.3
O.V.	10.4	11.0

CHART 6

MT TURKISH SMALL SCALE R&D
CUMULATIVE % VS AREA, MM SQ.



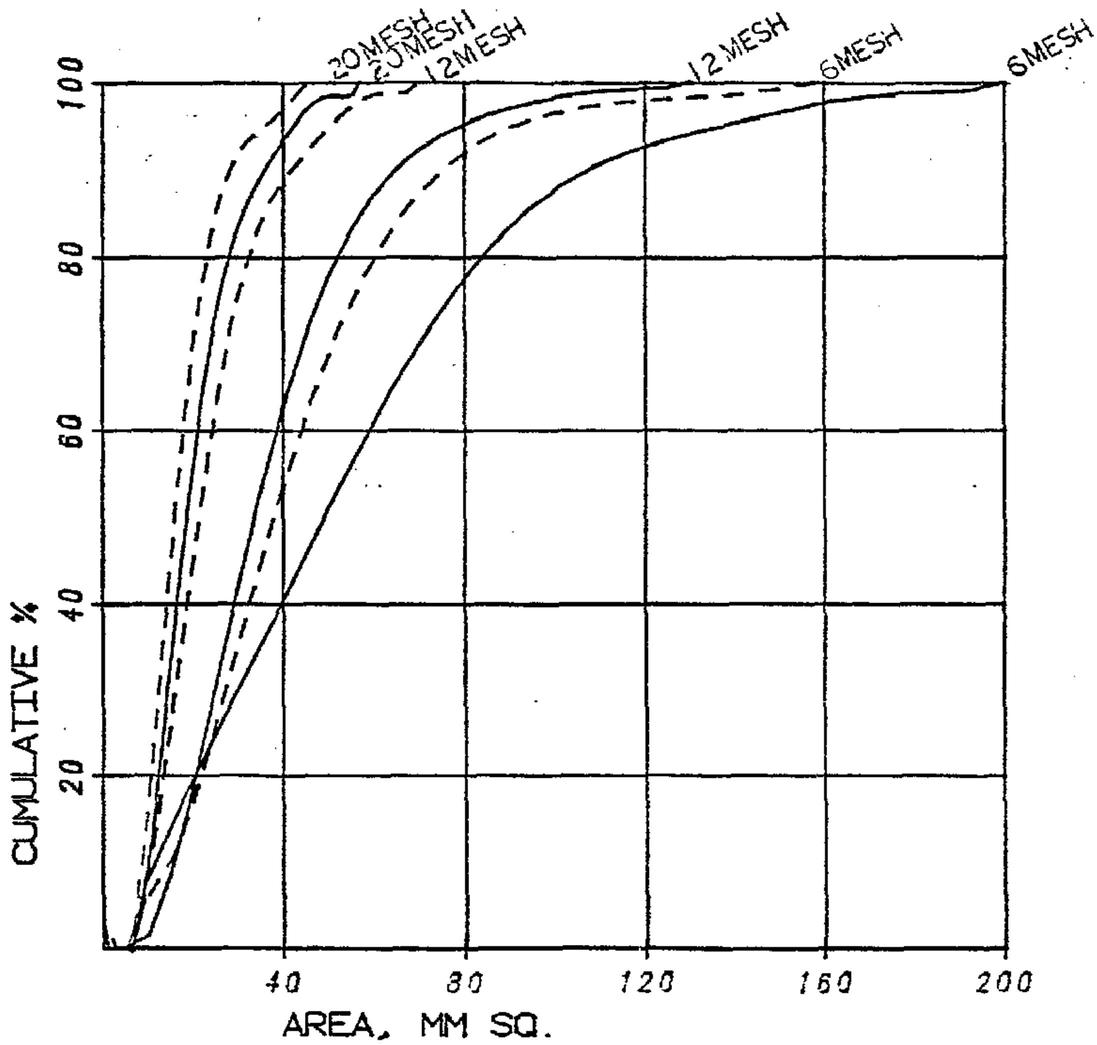
6,12,20,35,PAN SCREEN COMBINATION
PM SIEVE SHAKER - ROUND SCREENS

5/18/82

TK1.CH

CHART 7

DBC BURLEY LARGE AND SMALL SCALE R&D
CUMULATIVE % VS AREA, MM SQ.



SOLID CURVES – DBC BURLEY SMALL SCALE
DASHED CURVES – DBC BURLEY LARGE SCALE
6,12,20,35,PAN SCREEN COMBINATION
PM SIEVE SHAKER – ROUND SCREENS

5/17/82

DB2.CHT

A visual inspection of the actual samples showed that the small scale sample appeared to have a slightly wider cut width. Comparing the differences in average area versus average diameter for the two similar samples, shown in Table 15, demonstrates that the diameter parameter had less variation between the two samples than the area.

Table 15

DBC BURLEY

P.M. SIEVE SHAKER - ROUND SCREENS

AVERAGE PARTICLE SIZE

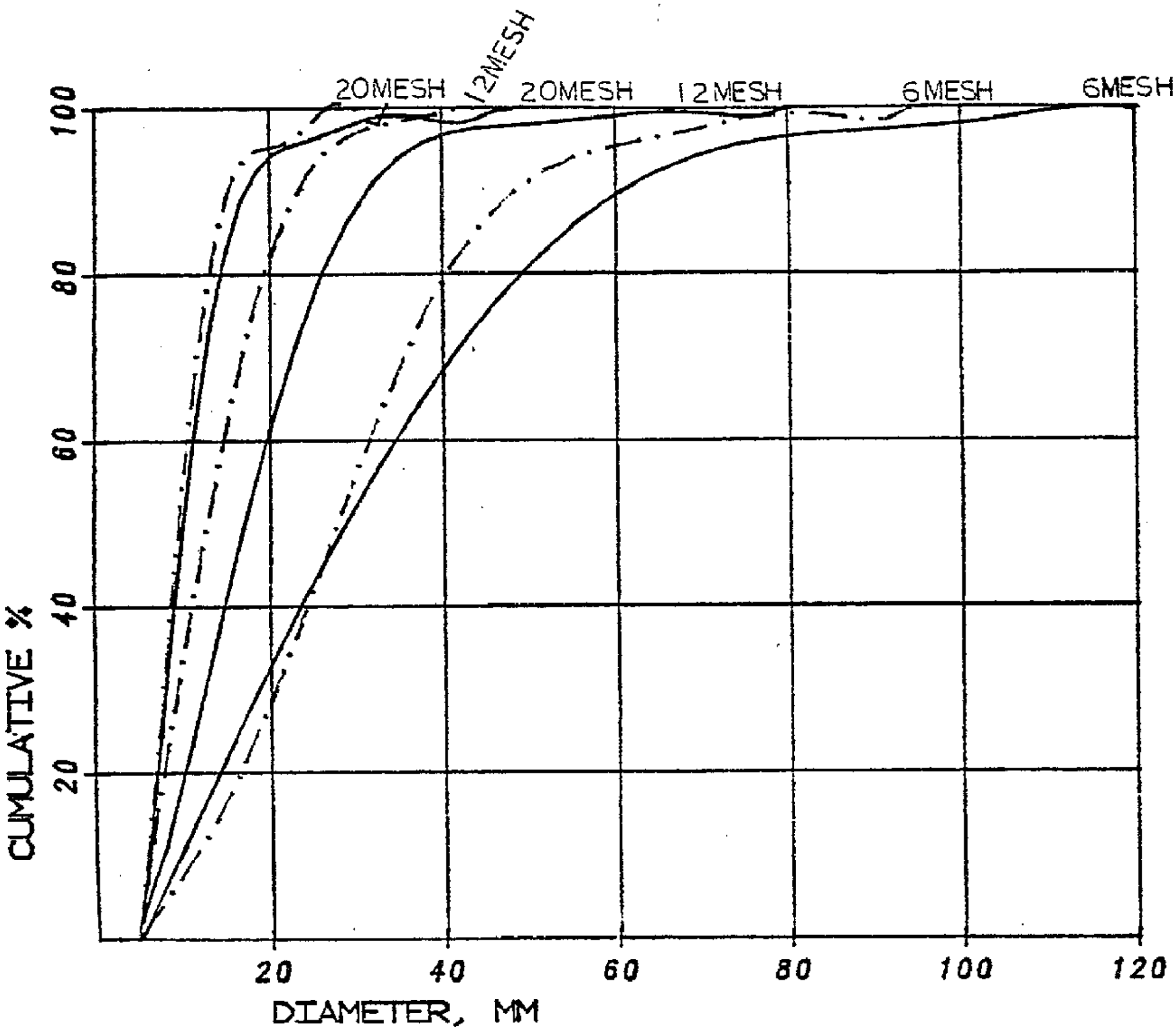
Mesh	Small Scale Area, mm^2	Small Scale Diameter, mm	Large Scale Area, mm^2	Large Scale Diameter, mm
On 6	62.6	35.8	48.0	32.1
(S.Dev.)	(41.9)	(22.1)	(27.0)	(15.6)
On 12	40.7	21.4	26.8	16.5
(S.Dev.)	(21.6)	(10.5)	(13.8)	(7.5)
On 20	22.9	12.3	18.6	11.3
(S.Dev.)	(13.1)	(5.71)	(8.3)	(4.4)

This fact is also evident in the diameter distribution curves for the DBC burley cut large and small scale, shown in Chart 8. It appeared from comparing these two samples that the sieve shaker was a more accurate indicator of particle diameter than area. Bearing the above observations in mind, diameter distribution curves were generated for all componenets tested to see if the diameter parameter was affected less by tobacco type than area.

Cumulative percentage vs. diameter curves for all the components tested are shown in Charts 9, 10, and 11.

CHART 8

DBC BURLEY LARGE AND SMALL SCALE R&D
CUMULATIVE % VS DIAMETER, MM



SOLID CURVES – DBC BURLEY SMALL SCALE
DASHED CURVES – DBC BURLEY LARGE SCALE
6,12,20,35,PAN SCREEN COMBINATION
PM SIEVE SHAKER – ROUND SCREENS

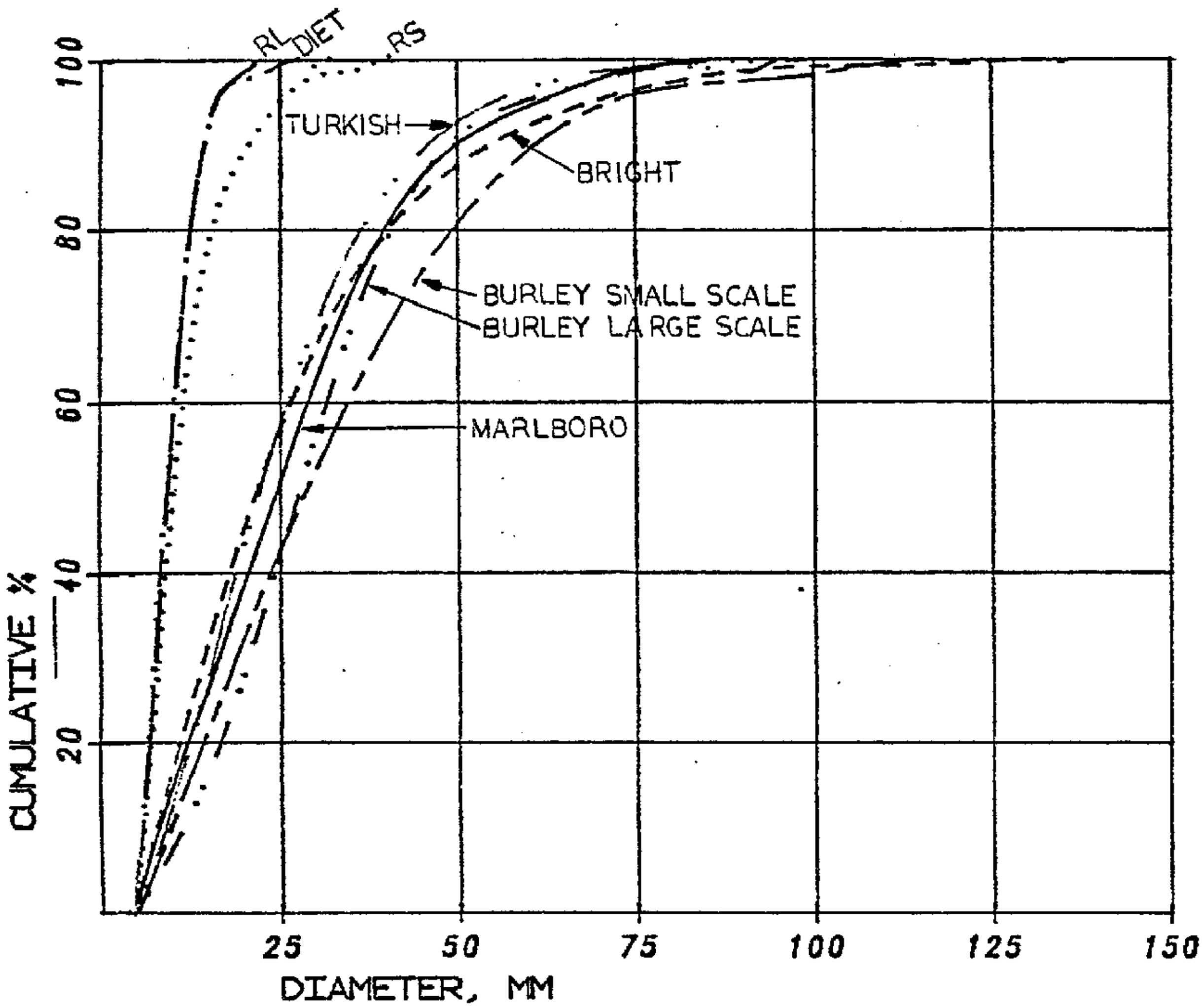
E '17/82

DB1.CHT

PM3000984395

CHART 9

CUMULATIVE % VS DIAMETER
6 MESH SCREEN SIZE DISTRIBUTION
MARLBORO,RIPPER SHORTS,DIET,RL,
DBC BRIGHT,DBC BURLEY,MT TURKISH



PM SIEVE SHAKER - ROUND SCREENS
6,12,20,35 SCREEN AND PAN COMBINATION

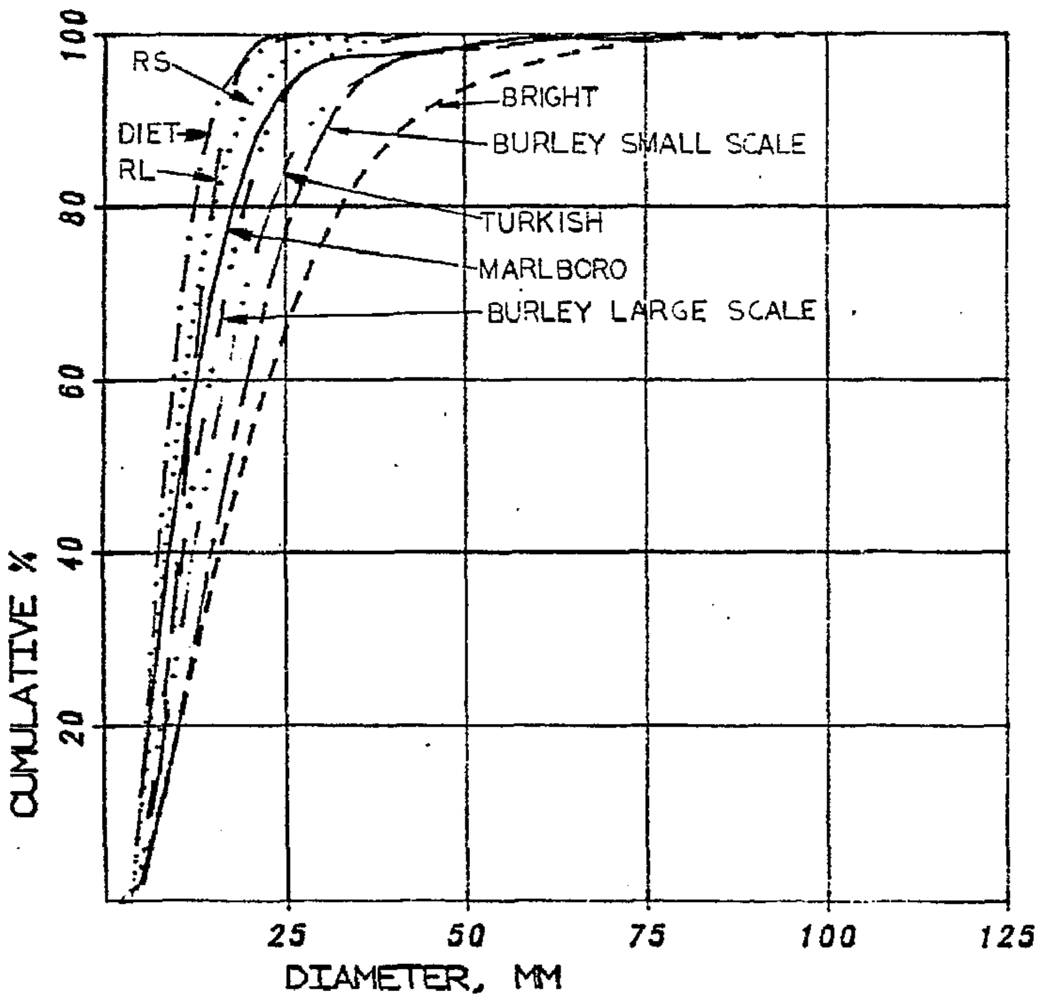
E/26/82

LEN1.CHT

PM3000984396

CHART 10

CUMULATIVE % VS DIAMETER
12 MESH SCREEN SIZE DISTRIBUTION
MARLBORO,RIPPER SHORTS,DIET,RL,
DBC BRIGHT,DBC BURLEY,MT TURKISH



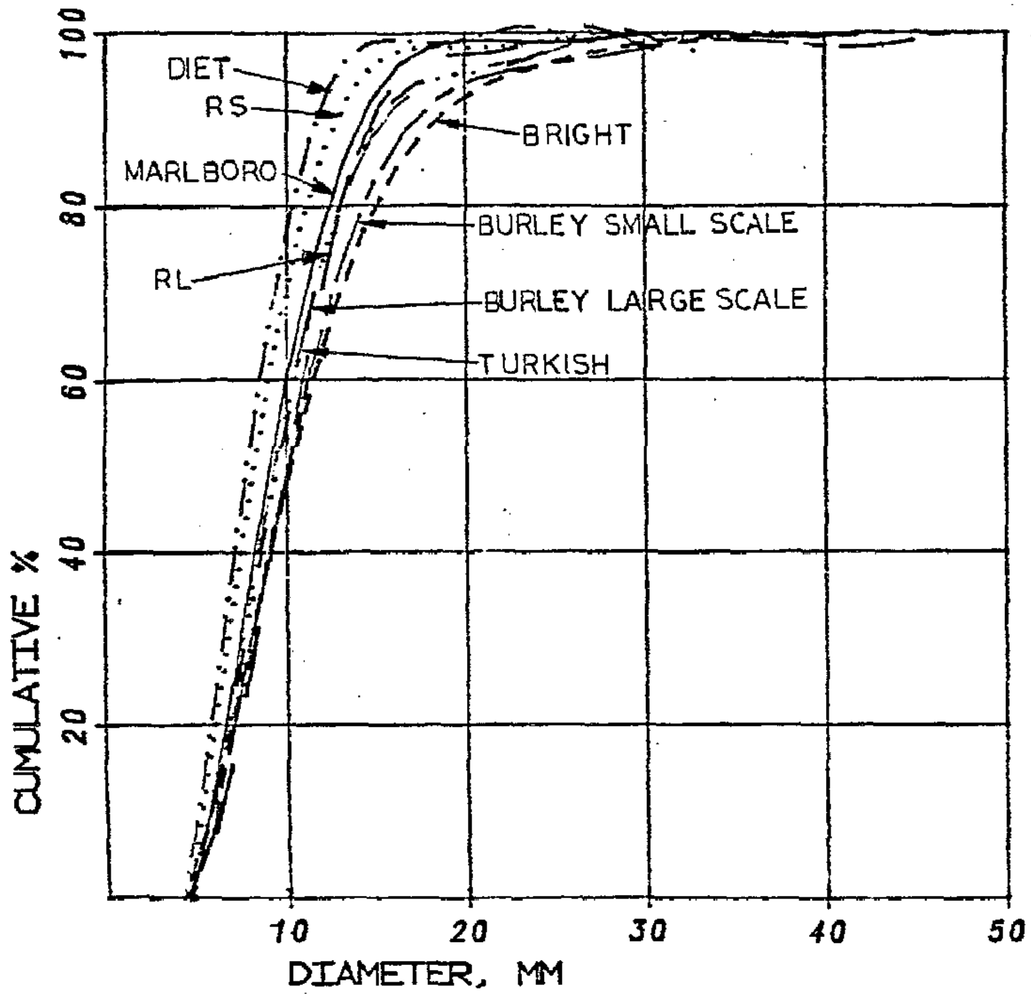
PM SIEVE SHAKER - ROUND SCREENS
6,12,20,35 SCREEN AND PAN COMBINATION

LEN2.CHT

PM3000984397

CHART 11

CUMULATIVE % VS DIAMETER
20 MESH SCREEN SIZE DISTRIBUTION
MARLBORO,RIPPER SHORTS,DIET,RL,
DBC BRIGHT,DBC BURLEY,MT TURKISH



PM SIEVE SHAKER - ROUND SCREENS
6,12,20,35 SCREEN AND PAN COMBINATION

F/03/82

LEN3.CHT

Table 16 shows the median area and diameter for all the tobacco types that were tested on the 6, 12, and 20 mesh screens. An inspection of the median range/median ratio shows that the overall variability of the two measuring parameters is about the same and so no increase in size prediction accuracy can be gained by using one parameter over another.

Table 16

SIEVE FRACTION SIZE DISTRIBUTION CURVES

MARLBORO, MARLBORO RIPPER SHORTS, DIET, RL, BRIGHT BURLEY, TURKISH

Mesh	Median Area For All Tobacco Types	$\frac{\pm \text{Range}}{\text{Median}} \times 100$
6	37.5 ± 17.5 mm^2	46.7
12	30.0 ± 10.0 mm^2	33.3
20	15.6 ± 1.9 mm^2	12.2

Mesh	Median Diameters For All Tobacco Types	$\frac{\pm \text{Range}}{\text{Median}} \times 100$
6	17.5 ± 9.8 mm	56.0
12	13.2 ± 3.8 mm	28.8
20	8.7 ± 1.3 mm	14.9

P.M. Sieve Shaker - Round Screens

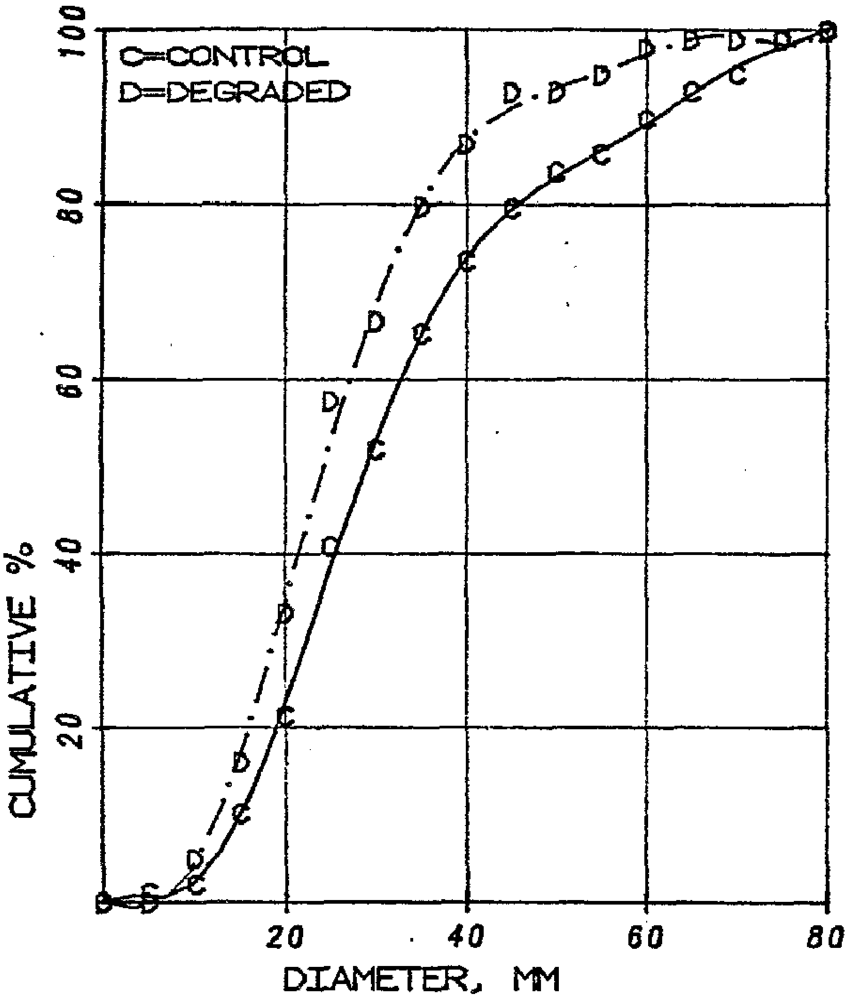
F. Sieving Analysis Comparison For Different Tobacco Types or Different Sieve Screen Combinations

Section II.E. has demonstrated that particle size distributions from sieve fractions are dependent on tobacco type and sieve screen size. The following test results will serve as a caution when trying to compare sieve results for different tobacco types and different screen combinations.

Using Marlboro cut filler a control sieving was done on the P.M. shaker with rectangular screens (10, 20, 30 and 50 mesh). A degraded sample of Marlboro cut filler was also sieved to represent Marlboro ripper shorts. Particle size distributions were generated from image analyses data for the control and "ripper shorts". Chart 12 shows the difference in the two diameter distributions on the top 10 mesh screen. The median diameter difference for the two samples is 5 mm. This difference will seem small when comparing the Marlboro and Marlboro ripper shorts diameter distribution curves of the top six mesh screen from the P.M. shaker with round screens (6, 12, 20, and 35 mesh) shown in Chart 9. The median diameter difference in Marlboro and Marlboro ripper shorts on the six mesh screen is 15 mm. While this is not a direct comparison because the "ripper shorts" were artifically generated for the rectangular screens it indicates some problems that may arise when trying to compare sieve results of different tobacco types and/or screen combinations.

CHART 12

DIAMETER PARTICLE SIZE DISTRIBUTION
MARLBORO 10 MESH CONTROL AND
MARLBORO 10 MESH DEGRADED



CONTROL	%LONGS = 44.35	AVG DIA = 35.5 MM
	SDEV = 16.8 MM	MEDIAN = 32.0 MM
DEGRADED	%LONGS = 27.38	AVG DIA = 28.9 MM
	SDEV = 13.1 MM	MEDIAN = 26.0 MM

PM SIEVE SHAKER - RECTANGULAR SCREENS

BUSY.CHT

PM3000984401

III. Kason Vibroscreen

The Kason Vibroscreen imparts multiplane vibration via a double shafted motor mounted to the screen stack. A schematic is shown in Figure 1. Eccentric weights can be added to the top and bottom shafts to vary the amount of horizontal and vertical vibration. In addition, the top and bottom weights can be offset in their angular relation to change the flow pattern of material across the screen. Oversized particles are fed across the screens in the desired flow pattern to the screen periphery where they are dicharged out a chute.

A. Operating Conditions - Kason

Operating conditions were picked after observing over 30 different shaking conditions. Three top eccentric weights and one bottom weight offset at 60° gave the best presentation of cut filler to the screens. The construction of the Kason made batch type sieving infeasible because of the time required to throughly clean the unit, (appproximately 45 minutes). Loading 100 grams of filler every five minutes for 50 minutes, (resulting in a 1000 grams test sample), gave a good continuous operating condition.

B. Particle Size Distribution - Kason compared to Rotap and P.M.

The Kason shaker was evaluated with Marlboro cut filler and a 4,6,10,20 screen and pan combination using the aforementioned operating conditions. Five sieving replications were done using both the Rotap, (4,6,10,20 screen and pan) and the P.M. shakers, (10,20,30,50 rectangular screens and pan), with tobacco from the same batch, for comparison. Image analysis was done on each measurable fraction from the three shakers. An inspection of the standard deviation/average ratios shown in Table 17 indicates that particle size distribution for the Kason is no better than for the Rotap or P.M. shaker.

Table 17

KASON - ROTAP - P.M. COMPARISON

Particle Area, mm2

	KASON			ROTAP		
Mesh	Avg.	S. Dev.	S. Dev./Avg.	Avg.	S. Dev.	S. Dev./Avg.
4	47.1	27.2	0.58	77.1	35.9	0.47
6	45.3	17.8	0.39	53.7	23.6	0.44
10	32.1	16.9	0.53	27.0	11.0	0.41
20	15.8	12.8	0.81	17.7	6.8	0.39

P.M. SHAKER - RECTANGULAR SCREENS

Mesh	Avg.	S. Dev.	S. Dev./Avg.
4	----	----	----
6	----	----	----
10	50.0	23.2	0.46
20	19.6	9.5	0.48

Particle Diameter, mm

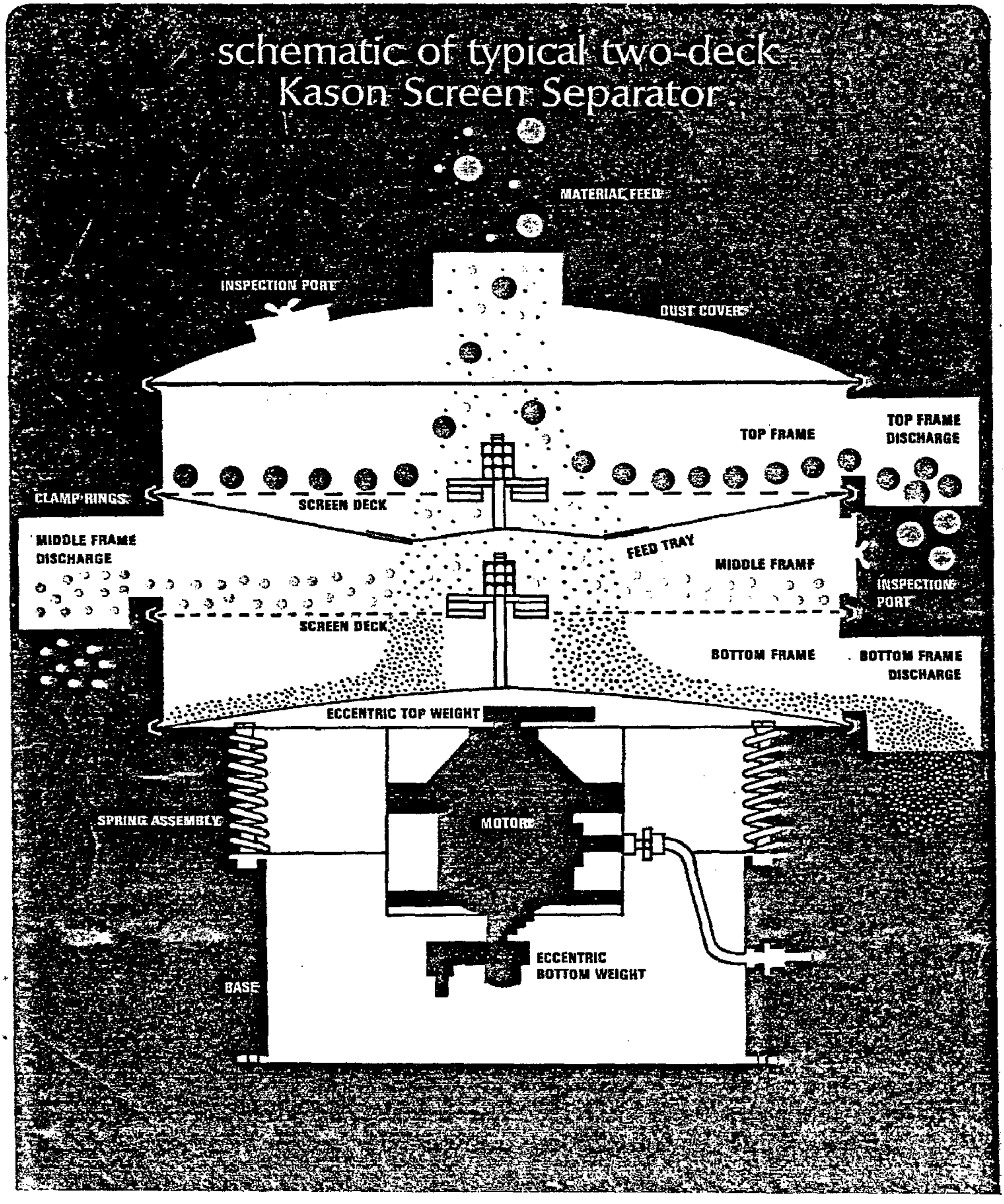
	KASON			ROTAP		
Mesh	Avg.	S. Dev.	S. Dev./Avg.	Avg.	S. Dev.	S. Dev./Avg.
4	25.1	13.7	0.55	34.6	18.1	0.52
6	19.0	8.9	0.47	22.7	11.8	0.52
10	16.1	8.7	0.54	13.2	6.2	0.47
20	8.7	7.7	0.88	10.1	3.0	0.30

P.M. SHAKER - RECTANGULAR SCREENS

Mesh	Avg.	S. Dev.	S. Dev./Avg.
4	----	----	----
6	----	----	----
10	25.5	11.8	0.46
20	10.9	5.02	0.46

Tobacco Type - Marlboro Cut Filler

FIGURE 1



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C. Perforated Plates - Kason

Perforated plates, as an alternative to sieve screens, were tested on the Kason. It was thought that a round perforated hole having only one dimension, the diameter, for the particle to pass through would cause less variation then a square screen opening with a width and diagonal. Also, the smooth surface of the perforated plate may be less likely to guide a particle through the hole than the weave of a wire screen. A 4,6,10,20 screen and pan combination was used as a control with a 3/16 inch diameter and 1/8 inch diameter perforated plate replacing the 6 and 10 mesh screens as a test. Marlboro cut filler was used as the sieved material. A comparison of the standard deviation/ average ratios indicated that the perforated plates did not significantly reduce the particle size distribution of the fraction trapped on them. The data is presented in Table 18.

Table 18

PERFORATED PLATE - KASON SIEVE SHAKER

TOBACCO TYPE - MARLBORO CUT FILLER

Control

Mesh	Mesh Open Area, mm^2	% Wt.	Area Avg. mm^2	Area S. Dev.	S. Dev. / Avg.
4	26.42	1.21			
6	11.22	9.89	45.9	25.8	0.56
10	3.53	56.15	21.5	9.9	0.46
20	0.74	28.83			
Pan	-	3.93			

Diameter

Mesh	Avg. mm	S. Dev.	S. Dev. / Avg.
4			
6	27.2	15.6	0.57
10	12.4	5.0	0.40
20			
Pan			

Test

Mesh	Mesh Open Area, mm^2	% Wt.	Area Avg. mm^2	Area S. Dev.	S. Dev. / Avg.
4	26.42	1.08			
3/16" Dia.	17.80	5.05	52.6	25.1	0.48
1/8" Dia.	7.92	34.49	18.2	9.6	0.53
20	0.74	52.15			
Pan	-	7.26			

Diameter

Mesh	Avg. mm	S. Dev.	S. Dev. / Avg.
4			
3/16" Dia.	25.6	12.5	0.49
1/8" Dia.	11.7	5.7	0.49
20			
Pan			

PM3000984406

IV. Alternate Separation Methods-Vacuum Separator

A vacuum chamber was designed as an alternate separation method to attempt to float tobacco particles by size in an air stream. It was theorized that the particles could be separated by varying the air flow rate in an open ended vertical duct. The group of particles with the smallest surface area would achieve the highest column height. However, the particles went from a point of static float to dynamic transfer too fast to extract the separated fractions. This problem was alleviated by drawing the total sample up through the duct against a 100 mesh screen. After the total sample was in the duct the air flow rate was gradually decreased while the separated fractions were caught at convenient intervals. The data in Table 19 shows that as the flow rate interval decreased the average area decreased, but the size variation, as measured by the standard deviation/ average size ratios, is not much better than for sieving.

Table 19

VACUUM SEPARATOR

TOBACCO TYPE - MARLBORO CUT FILLER

DECREASING FLOW RATE METHOD

Flow Rate	Avg. Area mm^2	S. Dev.	$\frac{\text{S. Dev.}}{\text{Avg.}}$	Avg. Dia. mm	S. Dev.	$\frac{\text{S. Dev.}}{\text{Avg.}}$
540 - 300 f/m	24.84	10.98	0.44	10.3	3.4	0.33
300 - 200	18.86	10.03	0.53	8.8	3.5	0.40
200 - 125	16.04	10.21	0.64	7.2	3.0	0.42
125 - 65	13.32	6.44	0.48	6.7	2.8	0.42
65 - 0	---					

Attempts were also made to draw particles up through sieve screens inserted in the duct. It was felt that the particle would travel with its largest area perpendicular to the flow of air and not be as likely to insert itself into the screen opening as was described in Section I.C., High Speed Video Films. After the total sample was drawn into the duct, the duct was placed horizontally, the vacuum shut off, and the duct was dismantled to collect the separated fractions. Table 20 shows that as the screen opening size decreased the average particle size decreased, but the size variability of the fractions was no better than sieving.

Table 20

PARTICLES DRAWN THROUGH SIEVE SCREENS

Mesh	Opening	Avg. Area mm^2	S. Dev.	S. Dev. / Avg.	Avg. Dia. mm	S. Dev.	S. Dev. / Avg.
7/16"	11.2mm	32.71	16.03	0.49	25.1	11.8	0.47
6	3.35	24.35	16.53	0.68	15.7	8.2	0.52
10	2.00	14.10	5.40	0.38	9.0	3.4	0.38

Tobacco Type - Marlboro Cut Filler

CONCLUSIONS

While particle size ranges for sieve fractions are quite large and overlap each other considerably sieving analysis can still give a useful indication of particle size ditribution for comparing similar processing conditions of like tobacco types.

No method of particle separation evaluated during this study showed significantly lower particle size variation for the separated groups than the P.M. sieve test with round ASTM specification screens, 6, 12, 20, 35 mesh screen and pan combination.

A standardization of the sieving analysis by Q.A. should help to make sieving results more reliable.

ACKNOWLEDGEMENTS

The many hours of sample sieving, tedious and diligent sample preparation for image analysis and data entry by Ken Hoffman and Darl Johnson are acknowledged and appreciated.

REFERENCES

1. ASTM D2947 - 74, "Standard Method for Screen Analysis of Asbestos Fibers," June 27, 1974.

2. K. A. Stover, "Quality Assurance Sieve Test," Memo to Mr. E. Pierce, January 23, 1981.

APPENDIX

The following model, developed by Mr. J. E. Tindall, estimates the sieving variation component of the variance. It is relatively small so that it could possibly be ignored, but the transformations to be discussed later are fairly sensitive to small changes in variation.

For a sinle tobacco particle:

$$X_{ijk} = \mu_i + S_j + \epsilon_{ijk}$$

X_{ijk} = The area, diameter, or length for a single tobacco particle.

μ_i = The mean (area, dia., or length) for mesh size i.

S_j = The contribution due to sieving j

$$E(S_j) = 0 \qquad V(S_j) = \sigma_s^2$$

ϵ_{ijk} = The error for a single particle within a mesh size and sieving.

The variation for a single tobacco particle within a sieving = σ^2

The variation for averages of 150 particles, including sieving variation = $V(\bar{x}) = \sigma_s^2 + \sigma^2/150$

Let R_s = The ratio of avg./S.D. for averages of 150 particles.

Let R = The ratio of avg./S.D. within a sample.

From above and the analysis of sieving variation.

$$R_s = \frac{\mu}{\left(\sigma_s^2 + \frac{\sigma^2}{150}\right)^{1/2}} \approx 12 \qquad 1$$

From the analysis of variation within samples

$$R = \frac{\mu}{\sigma}$$

$$\text{or } \sigma R = \mu$$

Substituting into equation 1 we can estimate

$$\sigma_S^2 = \sigma^2 \frac{R^2}{R_S^2} - \frac{1}{150}$$

The variation for a single tobacco particle including sieving variation is then

$$V(x) = \sigma_S^2 + \sigma^2 = \sigma^2 (1 + \frac{R^2}{R_S^2} - \frac{1}{150})$$

Sample Range Calculation

Rotap Sieve Shaker
6 mesh fraction from a 6,8,10,14,20 screen combination

Diameter Average, mm

Mesh	1	2	3	4	5	Average	Standard Deviation of Avgs.
6	21.4	36.2	31.8	33.0	29.0	30.3	5.60

Diameter Average/Standard Deviation

6	2.70	3.03	2.78	2.70	2.04	2.65

Exlcluding Sieving Variation

Let R = average diameter/standard deviation within a sample

$R = 2.65$

Let R_S = average diameter/standard deviation for the averages of 150 particles from each run

$$R_S = \frac{30.3}{5.60} = 5.41$$

$$\sigma = \frac{M}{R} = \frac{30.3}{2.65} = 11.43$$

Including sieving variation the total variation of tobacco diameters

$$= \sigma^2 \left(1 + \frac{R^2}{R_S^2} - \frac{1}{150}\right)$$

$$\text{Total variation} = \sigma^2\left(1 + \frac{(2.65)^2}{(5.41)^2} - \frac{1}{150}\right)$$

$$= 1.23$$

$$\text{Total standard deviation} = \sigma\,(1.11) = 12.69$$

$$\text{and } R = \frac{30.3}{12.69} = 2.39$$

Calculating the log-normal σ

$$\sigma = \left[\ln\left(1 + \frac{1}{R^2}\right)\right] = .40$$

The corresponding log normal μ

$$\mu = \ln \frac{m}{\left(1 + \frac{1}{R^2}\right)^{1/2}} = \ln \frac{30.3}{1.08} = 3.33$$

95% of the particles will fall in the range

$3.33 \pm (1.96 \times .40) = 2.55$ to 4.11

or transformed back

The 6 mesh diameter range for 95% of the particles is

12.6 to 61.7 mm